



Environmentally Friendly Coating Development at NASA Kennedy Space Center

Luz M. Calle

Wendy Li

Scott Jolley

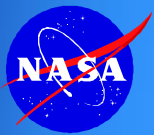
Paul E. Hintze

Paul.E.Hintze@nasa.gov

**Corrosion Technology Laboratory
NASA Kennedy Space Center**

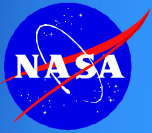
Corrosion Technology Laboratory

- New technology development
- Atmospheric and accelerated corrosion testing
- Corrosion engineering services for a unique environment
- <http://corrosion.ksc.nasa.gov>



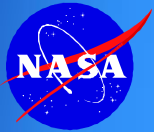
Corrosion Technology Laboratory

- Located in the Merritt Island National Wildlife Refuge
- Many systems still use environmentally unacceptable products



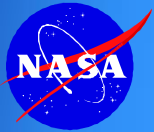
Corrosion Technology Laboratory

- Smart coatings that sense their environment and provide a response
- Self cleaning coatings
- Environmentally friendly powder coating



Smart Coatings

- The use of “smart materials” for corrosion sensing relies on a material undergoing a transformation through its interaction with the corrosive environment
- Chromate containing coatings are considered to be damage responsive

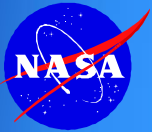


Smart Coatings

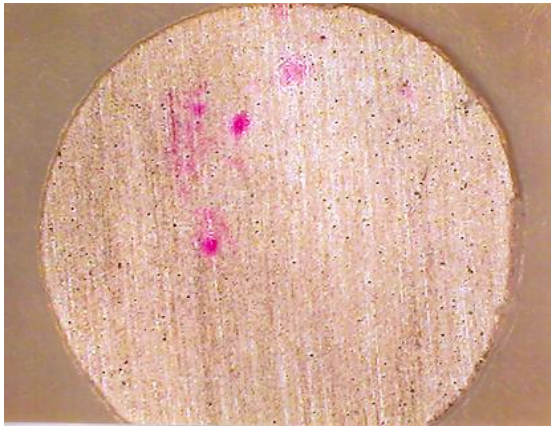
Examples of corrosion sensing coatings:

- Paint systems with color-changing compounds that respond to the pH changes that result from corrosion processes.
- Changes of coating compounds from non-fluorescent to fluorescent states.
- Release of color dyes on coating damage from incorporated dye-filled microcapsules.

The best coatings for corrosion protection provide not only barriers to the environment, but also a controlled release of a corrosion inhibitor, as demanded by coating damage and the presence of a corrosive environment. Past examples include coatings containing metallic zinc, such as the zinc-rich paint systems, and chromate.

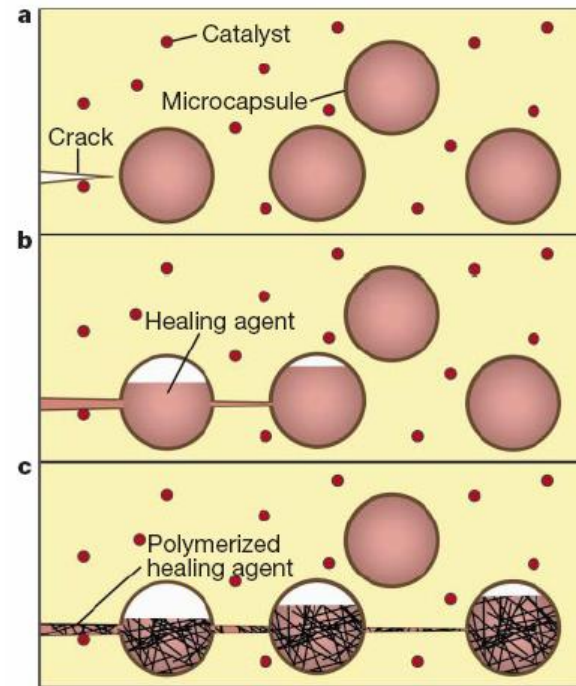


Smart Coatings

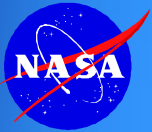


Sample coated with acrylic + phenolphthalein (critical PH =10) following exposure to 1M NaCl for 8 days.

http://www.mse.eng.ohio-state.edu/fac_staff/faculty/frankel/frankel.html

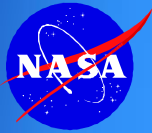


S. R. White, Nature, 409, 794-797, 2001



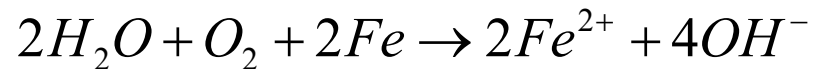
Smart Coatings

- Develop a paint system that can detect and repair corrosion at a very early stage without human intervention
- The system should be easily adapted for the delivery of new corrosion inhibitor compounds
- The system must work in different paint matrices

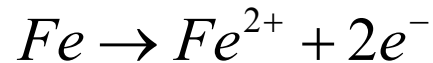


Electrochemical Nature of Corrosion

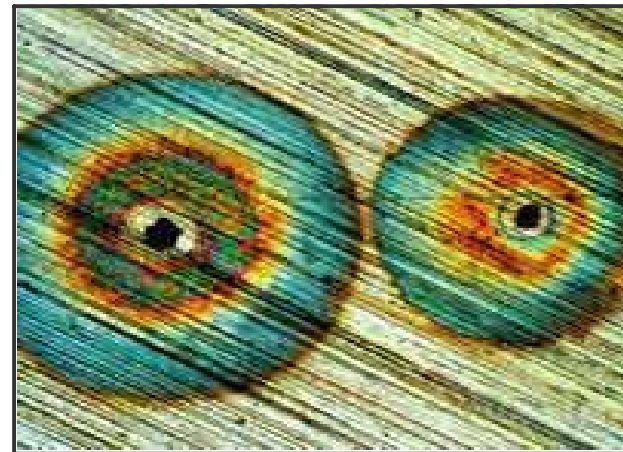
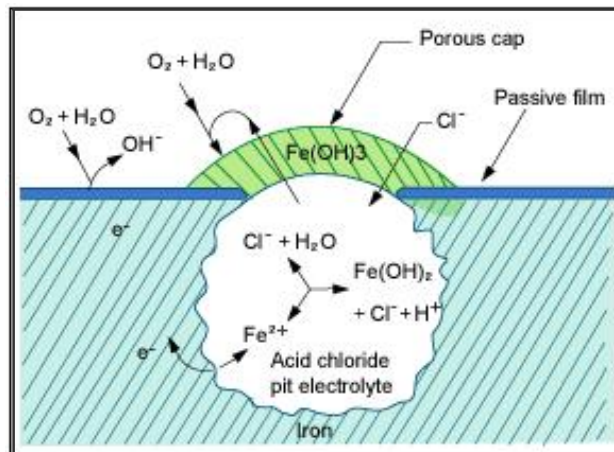
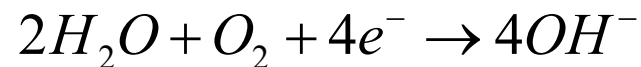
- Overall Reaction



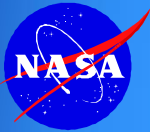
- Anodic Reaction



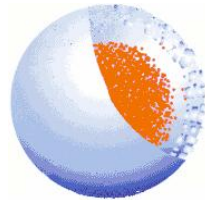
- Cathodic



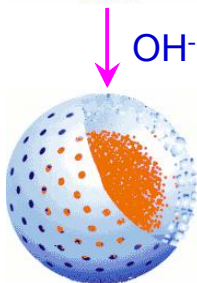
basic pH conditions at localized corrosion cathodic sites



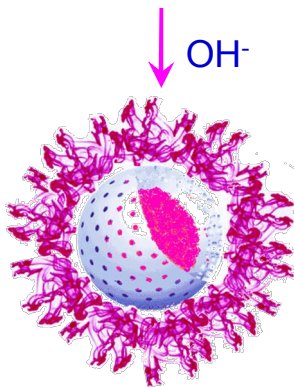
Smart Coatings



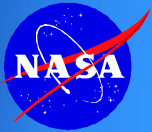
Microcapsule containing pH indicator
(inhibitor, self healing agents)



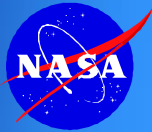
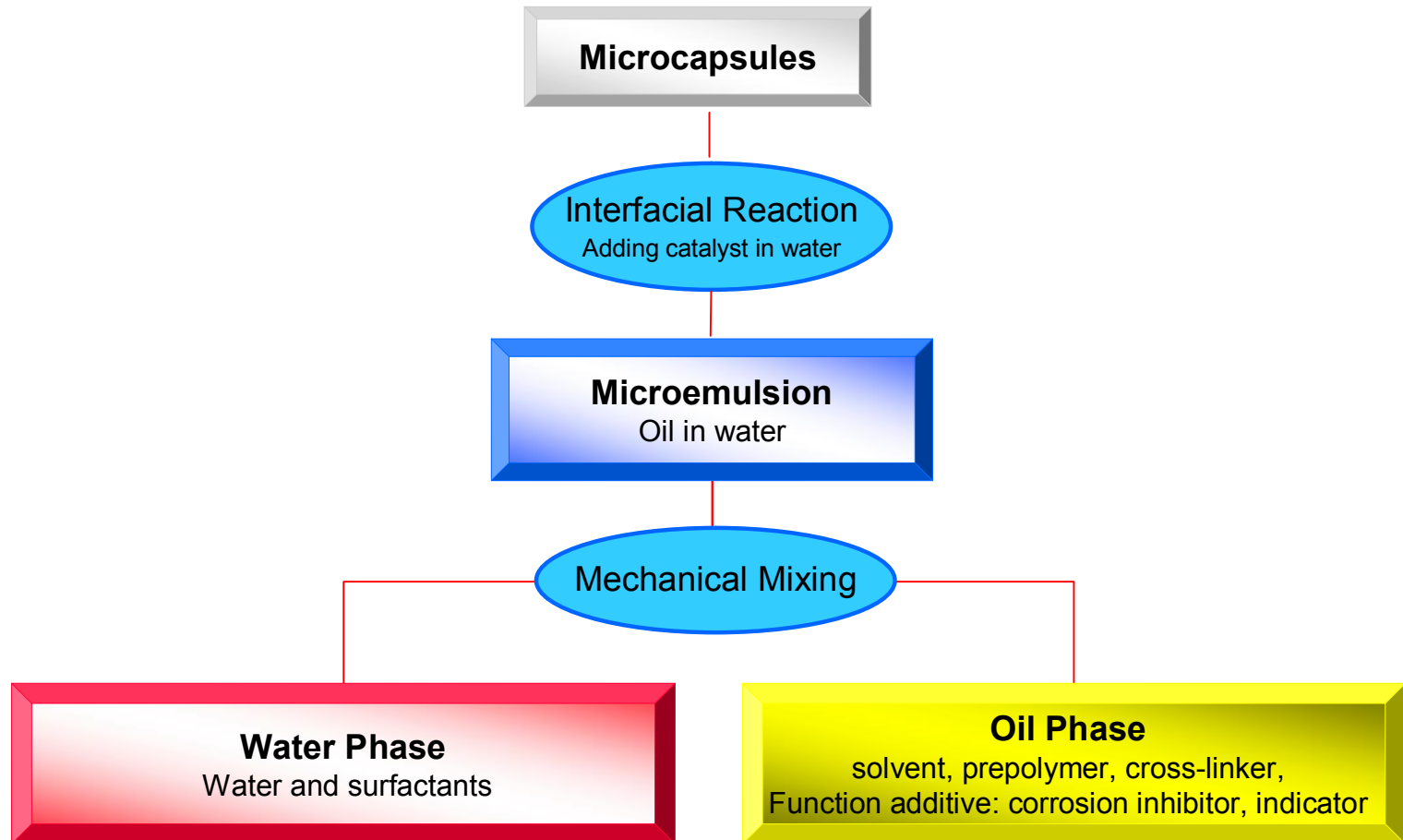
The shell of the microcapsule breaks
down under basic pH conditions

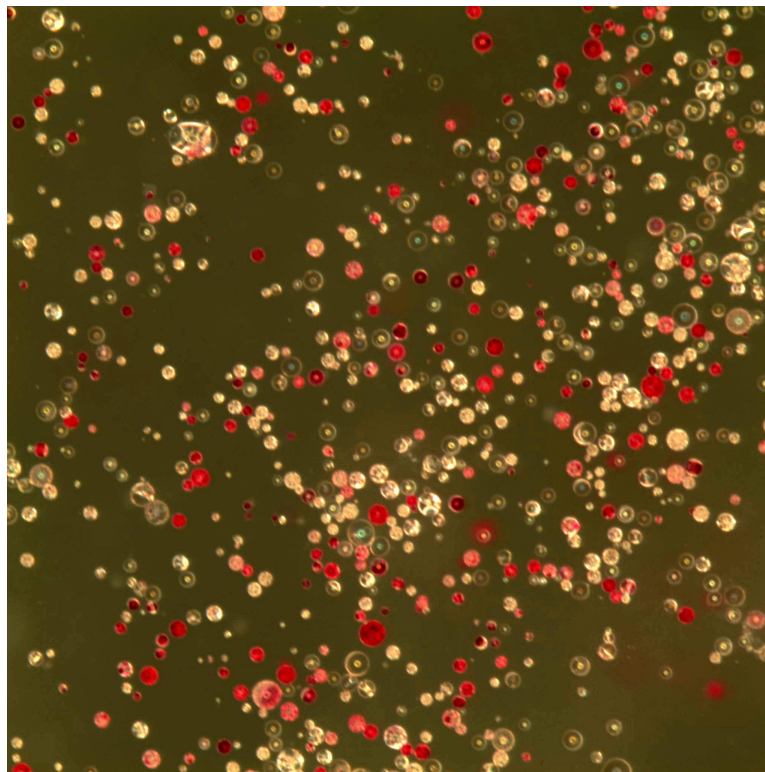


pH indicator changes color and is
released from the microcapsule under
basic conditions

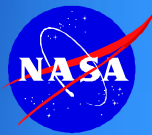


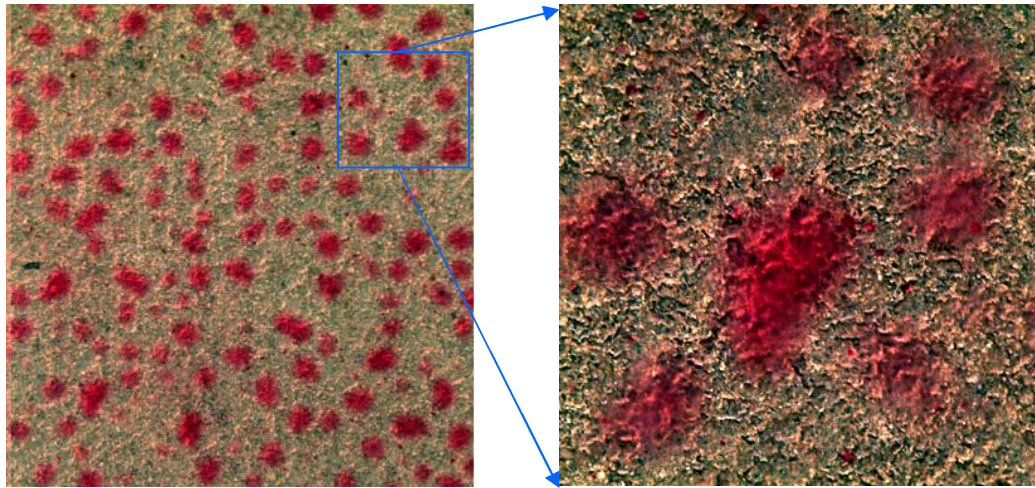
Microcapsule Synthesis



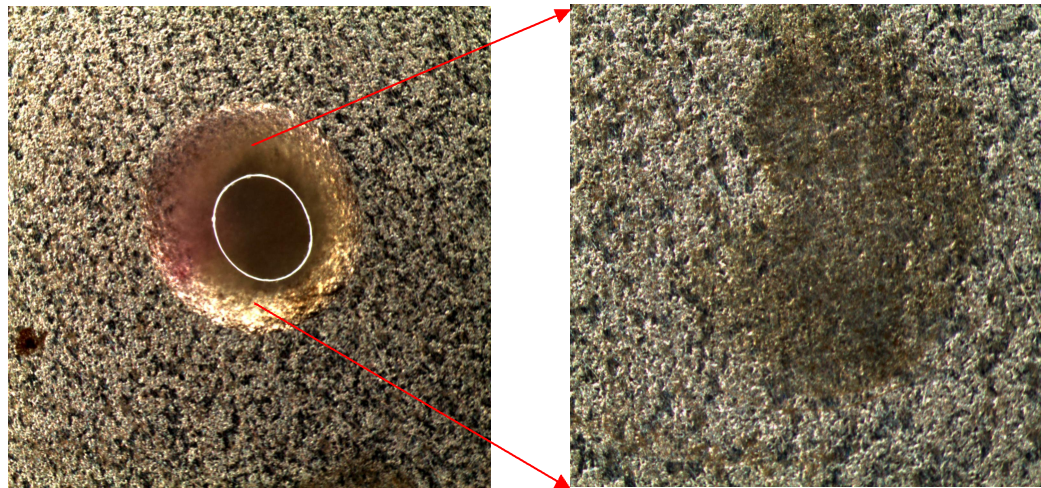


Color change due to Microcapsules in solution responding to basic pH conditions

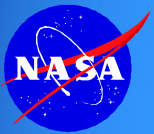




Microcapsules in paint responding to basic pH conditions

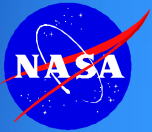


Microcapsules indicating presence of localized corrosion



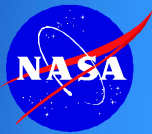
Smart Coatings

- Early detection of corrosion
 - Fluorescent pH indicator – Easy to detect, even in very small amounts
- Versatility of the microcapsule design
 - Successful encapsulation of water soluble and water insoluble compounds
 - Can be incorporated into different dispersion systems
- Currently working new inhibitor mixtures and paint systems



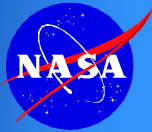
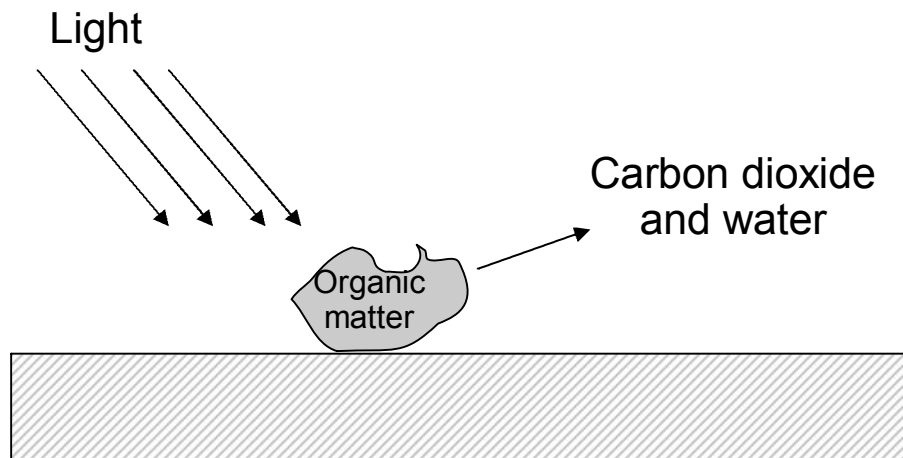
Self Cleaning Coatings

- Develop self-cleaning coatings that remove contamination without human intervention
- Coatings that chemically remove organic contaminants, leaving no residue
- Cleaning effect comes from titanium based photo-catalysts



Self Cleaning Coatings

- Catalyst absorbs light and creates a transient reactive species on surface
- Reactive species reacts with contaminant

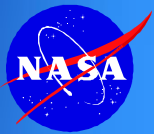
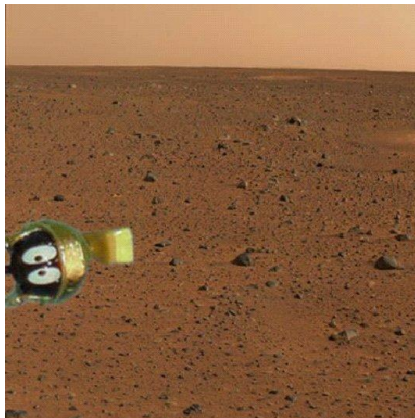


Self Cleaning Coatings

- Protect ground support equipment, spacecraft and vehicle assembly areas from contamination

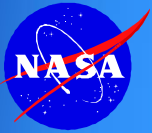


- Planetary protection policies address the prevention of planetary cross contamination



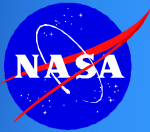
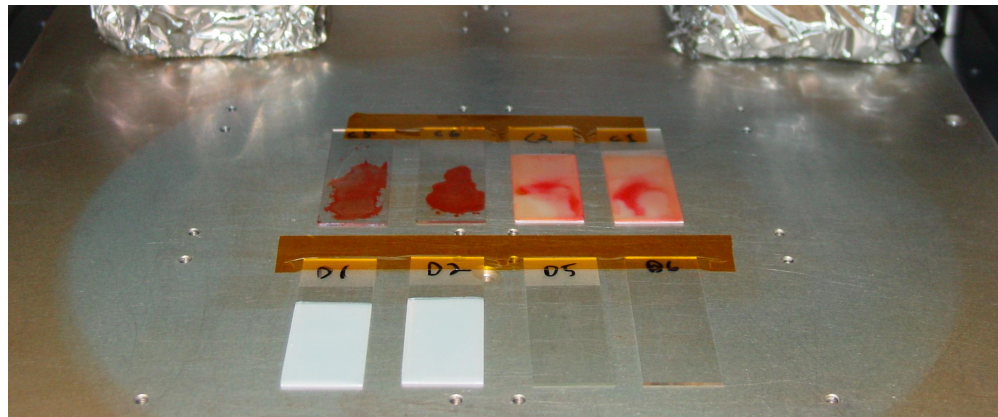
Self Cleaning Coatings

- Incorporate self cleaning catalyst into a variety of coatings that would be used in the KSC environment
- Make sure the catalyst has no adverse effects on the coating



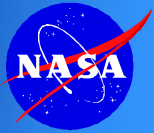
Self Cleaning Coatings

- Currently, have only tested catalyst and a few coatings in the laboratory using the reduction of a red dye
- Achieved over an 80% reduction for the best catalyst and 50% reduction for a coating in 48 hours
- 66% reduction in Mars chamber corresponding to 9 Martian sols



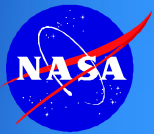
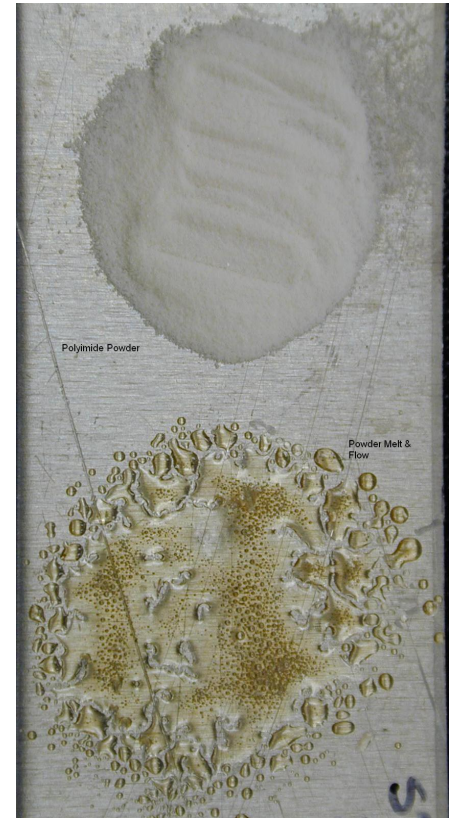
Self Cleaning Coatings

- Test the coatings self cleaning properties after exposure to the KSC environment
- Evaluate the coatings ability to clean vapor phase contaminants



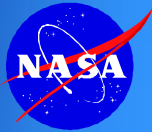
High Performance Powder Coatings

- Formulation applied to metal surfaces as a 20 – 100 micron powder
- Object baked to achieve melt, flow and cure of coating
- Common powder coatings include urethanes, epoxies, acrylics and polyesters
- No VOCs, overspray can be recycled
- Used on automobiles, appliances and architectural applications



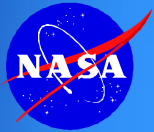
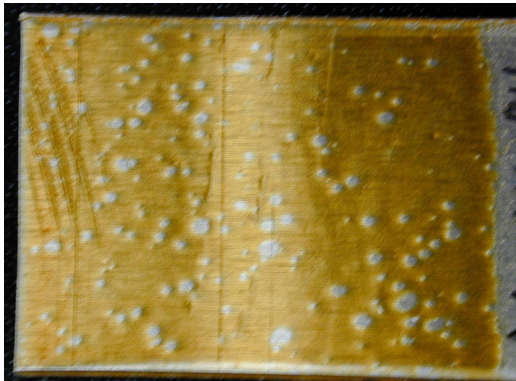
High Performance Powder Coatings

- **Why polyimide coatings?**
 - Provide excellent thermal stability, solvent resistance and electrical properties
 - Possible replacement for chromium containing coatings on aircraft
 - Low melt polyimides were developed at KSC for wire repair
 - Never been made into a powder coating
 - Unworkable using conventional methods (extrusion, solvents etc...)



High Performance Powder Coatings

- Several resins have been prepared with promising results
- Excellent results for flow, adhesion and toughness
- Issues surrounding surface wetting still need to be addressed



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